

DISTRIBUTION OF MOLLUSCS IN AND AROUND THE CORAL REEFS OF THE SOUTHEASTERN COAST IN INDIA¹

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(With three plates, four text-figures and a map)

INTRODUCTION

The report presents the results of a synecological analysis of the molluscan fauna associated with the different hard and soft substrates in and around the fringing coral reefs of Palk Bay and Gulf of Mannar around Mandapam (Map 1) between the longitudes 79° 8' and 79° 14' E, and latitudes 9° 12' and 9° 18' N. This study forms part of a programme of survey of the reef-associated living resources of the seas around India. An attempt has been made to identify and to assess the comparative dominance of the molluscan communities in the different habitats as also to delineate the physical and biological factors that influence their selection of habitats.

The molluscs of this area are fairly well known, thanks to the works of Hornell (1915, 1917, 1922, 1951), Gravely (1927), Satyamurthi (1952, 1956), Rao (1970), Jones (1970), Silas (1968) and many others whose contributions are listed by Nair and Rao (1974). Though about 450 species are known from this area, there appears to be little attempt in the past to discuss the synecological aspects of molluscan distribution but for the work of Rao and Sundaram (1972). Satyamurthi (1952, 1956) has mentioned the natu-

ral habitat of many species he has described. The present collection includes only 112 species (Table 2)—roughly one fourth of the known species, partly because we have not accounted the many dead shells found except from the raised reefs. In the recent past there has been considerable destruction to reefs due to indiscriminate quarrying of corals and this has directly caused a dwindling of the molluscs associated with the reefs. (Pillai 1975).

MATERIALS AND METHOD

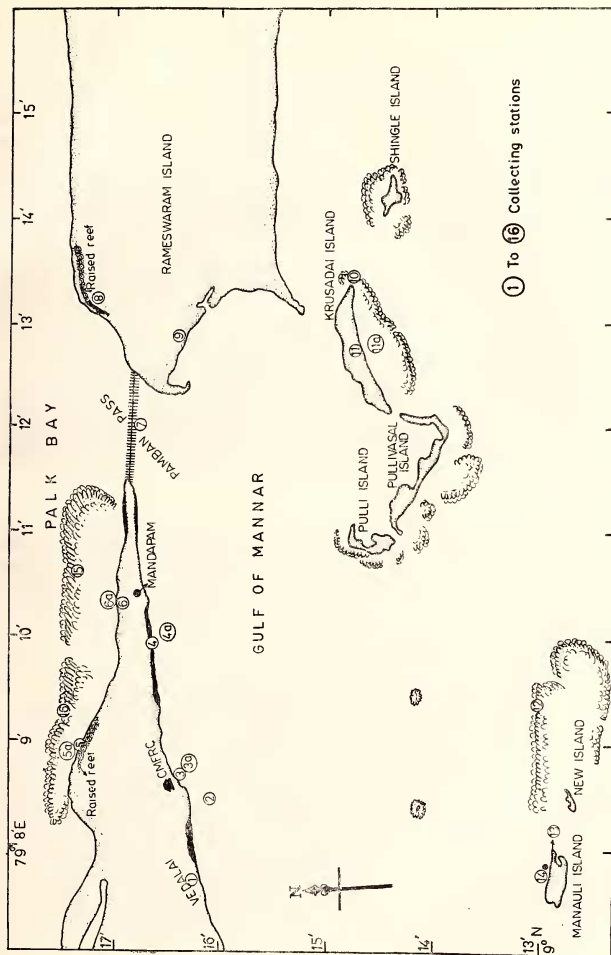
Sixteen stations (Map 1) were selected, representing almost all the types of specialised habitats seen in this region.

The collections were made at low tide with the aid of face mask and snorkel, where depth permitted. In Palk Bay, the survey was carried out during August-September; in Gulf of Mannar, during January-February; when calm conditions prevailed. The unit for the survey and population analysis was a sample plot of quarter square metre marked out with the aid of a metal frame. In addition to these observations and analyses relevant portions of our earlier studies on corals (Pillai 1971a, 1972) and on boring bivalves (Appukuttan 1972) were also incorporated to make the account comprehensive. The nomenclature of the various intertidal zones used in this work is that of Lewis (1955, 1961 & 1972), and Newell (1969).

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MOLLUSCS IN AND AROUND CORAL REEFS



① To ⑯ Collecting stations

Map. 1. Area of investigation with different collecting Stations.

Details of stations studied:

Station 1. Vedalai, Gulf of Mannar. Sandy beach with open circulation, not protected by a reef. Dominated by Wedge-clams.

Station 2. About 700 m east of station 1 Sublittoral zone. Sandy bottom with seagrass bed. Depth about 0.5 m at low tide with a very high concentration of *Pinna bicolor*.

Station 3. About 300 m further east of station 2 below the CMFR Institute Jetty in Gulf of Mannar. The groyne of the Jetty in the upper zone provides an artificial habitat and is designated as 3, whereas the lower zone, about 50 m into the sea with a depth of about 50 cm at low tide, is marked 3a. Station 3a has a rich growth of higher algae. The upper zone is typical eulittoral while lower zone is sublittoral.

Station 4. About 1 km east of station 3 in Gulf of Mannar. The station slopes steeply from the elevated sandstones on the shore at a height of nearly 2 m to the low water mark. (Pl. 1, Figs. 1, 2) The upper part of the sand stones represents the littoral fringe zone while the lower zone is typically eulittoral. Littorinids are the dominant molluscs.

Station 5. Manacadu Point on the Palk Bay side of the Mandapam peninsula with remnants of a raised reef. Semifossilised coral boulders on the water mark which harbour many gastropods and is marked 5, is typically eulittoral. (Pl. 3, Fig. 1). The semifossilised coral boulders in the lagoon bottom at a depth of 0.5 to 0.75 m at low tide, marked station 5a, is sublittoral with a dominant assemblage of bivalves.

Station 6. The landing centre at Mandapam in Palk Bay. The upper sandy beach in the eulittoral zone, marked station 6, and the lower sublittoral with algal growth and sandy bottom is 6a. (Plate 3, Fig. 2).

Station 7. The blocks of sandstones under the

Pamban Bridge subjected to heavy current, mostly submerged with a luxuriant growth of edible algae on them.

Station 8. Northwestern tip of the Rameswaram Island on Palk Bay side. A raised reef with an elevation of nearly 1.5 m. Equivalent to Littoral fringe zone.

Station 9. Western side of Rameswaram Island near the Pamban bridge. Sandy eulittoral zone.

Station 10. Eastern tip of Krusadai Island in the Gulf of Mannar where the reef with a boulder zone approaches the shore. Eulittoral, with a dominance of gastropods. This is the only undisturbed reef available for investigation at present here.

Station 11. Sandy beach at the southern side of Krusadai Island. A lower zone in the lagoon with corals and algae is designated as 11a. The beach is protected by a fringing reef.

Station 12. The reef of Manauli Island in Gulf of Mannar. The reefs have mostly been removed and only a few scattered, dead, up-turned colonies of *Acropora* and *Porites* are seen, with intermittent large areas of sand.

Station 13. The lagoon of Manauli Island. Bottom sandy with sea grass and other edible algae. Mostly submerged and represents the sublittoral zone. The nearshore area is without vegetation and gets exposed at low tide.

Station 14. A mangrove growth at the north-eastern shore of Manauli Island. A mud flat, that gets exposed fully at low tide, and teaming with *Cerithidea*, adjoins the mangroves.

Stations 51 and 16. The reef of Palk Bay along the Mandapam Peninsula. The reef crest, outer and inner sides of the reefs were investigated. The outer reef shows a preponderance of ramose corals while the inner (shoreward) side is rich in massive corals (Pillai



1. Beach sandstones at Station 4.
2. Closer view of the square cut blocks.



1. Exposed lagoon bottom at Mandapam Palk Bay showing the unvegetated sand, west of Station 5.
2. *Ulva reticulata*. Large quantities are found washed ashore during September in Palk Bay shore inhabited by several gastropods.

1971a). The reef crest is typical eulittoral and is devoid of any living corals.

THE MOLLUSCAN ASSEMBLAGES IN DIFFERENT HABITATS

Sandy shore

(Without vegetation)

The mainland coast along Mandapam and the shores of the near by sand cays in Gulf of Mannar (Stoddart and Fosberg 1972) are mostly sandy, though outcrops of sandstones are found along the mainland coast. Typical rocky shore does not exist. The beach sand is fine-grained, the grains ranging from 2 to 4 mm in size and with an admixture of corals and molluscan shells. The molluscan fraction is mostly of the shells of *Cerithium*, *Umbo-nium*, *Dentalium*, and *Donax*. The subsurface has a high percentage of black clay (at a depth of 10 cm and below) with a foul smell of hydrogen sulphide. At Mandapam (Palk Bay) the grain size increases towards the deeper layers with an unconsolidated grit of gastropod shells. The grain size as well as the calcareous content of the beach sand varies from place to place. At station 1 the sand is 0.5 to 1.5 mm in grain size and a sample from the surface yielded 85.66% of insoluble silicon in hydrochloric acid and 14.44% soluble calcareous matter. However, the beach sand of the islands has a very high percentage of calcareous matter. Analysis of a sample from station 11 in Krusadai Island yielded 96.48% of soluble calcareous matter in hydrochloric acid. The high calcareous content in Krusadai is mostly due to the presence of coral fragments. The following discussion of the molluscs of sand is based on stations 1, 6, 9 and 11.

At the low water mark, *Murex trapa*, *Bursa spinosa*, *Drupa margiriticola* and *Cerithium* spp. are present. During December,

1973 and January, 1974 *Aplysia lineolata* was found in fair numbers at Vedalai. The mud flat at the northern side of the Manauli Island which gets exposed at low tides harboured plenty of *Cerithidea fluviatilis*, their number varying from 100 to 150 per square metre. However, along the mainland coast this gastropod is rare and replaced by *Cerithium trailli*.

On the eulittoral beaches the molluscan fauna is rich, composed of *Donax* spp. and *Atactodea glabrata* with a high concentration of the individuals at the mid-beach at a depth of 20 to 25 cm. The deeper muddy substratum is unsuitable for these filter feeders. However, there is local variation in the occurrence and abundance of these two genera of burrowing bivalves. *Donax* spp. are common along the mainland coast. At Station 1 their concentration was 40 to 60 individuals per square metre in January, 1974, represented mainly by *D. faba* and *D. cuneatus*. Alagarwami (1968) reported a concentration of 89 to 217 clams from the same site during December 1962 to November, 1963. He has also reported the presence of *D. spinosus*, *D. apertus* and *D. incarnatus* at Vedalai, however, our collections during January, 1974 yielded none of these species. On the Palk Bay side the intensity of *Donax* was less, only 10 to 15 individuals/sq. metre were recorded. This may be due to the more muddy nature of the subsurface sand along Palk Bay coast. At station 1, though *D. faba* and *D. cuneatus* occur, there seems to be a sort of grouping among the species, i.e. individuals of the same species incline to concentrate. When one sample plot yielded one species, another plot yielded only the other though both *faba* and *cuneatus* are found at the same level of the beach. Further, individuals from the same plot are more or less of the same size probably of

same age. This shows that there is very little tendency among the members to disperse. The burrowing clams of the islands are predominantly *Atactodea glabrata* (20-30/sq. m in Krusadai). *Donax faba* and *D. cuneatus* are rare.

The ecological factors that determine such a distribution of *Donax* along the mainland coast and *Atactodea* on the island are not clear. The calcareous content of the beach sands on the islands, as already mentioned, is much higher than that of the mainland coast. Further, the mainland coast is subjected to more wave action and beach circulation than the islands protected by the fringing reef. The tendency of *Donax* to concentrate on unprotected beaches with high circulation of water was already pointed out by Taylor (1968). He also stated that though *Donax faba* and *Atactodea glabrata* may occur in the same beach at Mahe, Seychelles, the latter species always occupies a higher and more sheltered position on the beach. In general,

our observations also show that protected island beaches with a high calcareous content in this area form a favourable habitat for *Atactodea*, while fine-grained sand with very little calcareous content, with good water circulation, is the more favoured habitat for *Donax* spp.

The sandstones :

Blocks of elevated sandstones are found along the Mandapam Peninsula on the Gulf of Mannar side. A small outcrop is seen near the Pamban Bridge at the Palk Bay side also. The sand cays situated in the vicinity of Mandapam are devoid of any sandstone outcrops (Stoddart and Fosberg 1972), though Reddiah (1972) has reported its occurrence along the beaches of Appa Island, further north, in the Gulf of Mannar. The sandstones are elevated up to 2 m in certain places showing signs of wave-cut aberrations. Structurally, they are conglomerate of sand grains of different sizes with molluscan shells, predomi-

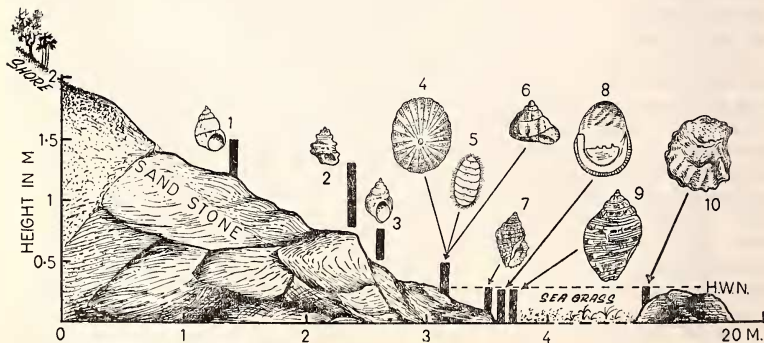


Fig. 1. Zonation of various molluscs at Station 4. The thick vertical lines show the vertical range of species. 1. *Littorina undulata*; 2. *Nodilittorina pyramidalis*; 3. *N. leucostica*; 4. *Cellana radiata*; 5. *Craspidochiton* sp.; 6. *Trochus radiatus*; 7. *Drupa margeritcola*; 8. *Nerita* spp.; 9. *Thias (Purpurea) rudolphi*; 10. *Crassostrea cucullata*.

nantly of *Cerithium*. The sandstone assemblage of molluscs discussed below is based on observations at station 4.

In the absence of any rocky outcrops in this area, the typical rocky shore animals occupy the sandstones. At station 4 the molluscan fauna display a pattern of vertical zonation (Fig. 1). At the higher levels representing the Littoral fringe zone (Lewis 1961, Morton and Challis 1969, Newell 1970, Arudpragasam 1970) the dominant animals are the littorinids. At a height of nearly 1.75 m from the high neap tide level *Littorina undulata*, *L. krausi* and large individuals of *Nodilittorina pyramidalis* are found. The first mentioned species is found at the highest zone and displays a lot of phenotypic variations in the colour of their shells. It has a tendency to crowd together under the overhanging cliff and in crevices. The species is not generally seen on the surface of sandstones exposed to scorching sun. *L. krausi* is rare here. Though *Nodilittorina pyramidalis* is found mixed with *L. undulata* its concentration is at a lower level, where they have a tendency to flock together, sometimes in hundreds as we observed in January, 1974. Lower down, below the zone of *N. pyramidalis*, there is a heavy concentration of *Nodilittorina leucostica* where there is a constant splash of water. From a sample plot we collected as many as 621 specimens of *N. pyramidalis* and from a plot below that 180 specimens of *N. leucostica*. However, we have not observed a zone where these two species mingle, the position of the former being always above the level of the latter. Among the four species of littorinids found here, *N. pyramidalis* has the widest range of vertical distribution from the upper limit of the littoral fringe to the upper limit of the eulittoral zone. The younger specimens occupy a lower level while the large adults migrate to the

upper level of the littoral fringe. A similar pattern of vertical distribution of this species at Ceylon was recorded by Arudpragasam (1970), while Atapattu (1969) observed a similar phenomenon in *N. granularis*.

Size range and density of population of littorinids at station 4 during January, 1974 was analysed. In random samples of 284 specimens of *Littorina undulata*, the height of shells ranged from 2 to 13.8 mm, the majority being in the range of 8 to 10 mm (Fig. 2b); only 10 specimens were in the range of 1 to 6 mm. 180 specimens of *N. leucostica* examined from a sample plot ranged 1 to 11 mm, the maximum number being in the range of 8 to 9 mm (Fig. 2a). A sample plot yielded 621 specimens of *N. pyramidalis* ranging from 1 mm to 10 mm, the maximum being in the range of 6 to 7 mm (Fig. 2 e). Presence of small specimens in the range of 1 to 2 mm in the natural population of littorinids suggests that breeding and recruitment of individuals to the population occur shortly before January. On the Ceylon coast recruitment of *N. granularis* to the population takes place at the tail end of Southwest monsoon, i.e. during October to November (Atapattu 1969). This seems to be true of all the members of the *Littorina* and *Nidilittorina* of this area.

Below the zone of littorinids (eulittoral zone) occur the limpets *Cellana radiata* and a small species of *Craspidochiton*. The edible oyster *Crassostrea cucullata* is seen fully exposed at low tides, the habitat of which in general is within a narrow belt between tide marks (Hornell 1951). They attach firmly to the sand stones. At low water marks the carnivorous gastropod, *Thias (Purpurea) rudolphi* and *T. carnifera* as well as *Drupa margiriticola* are seen. *Cerithium trailii* are also found in fair numbers. Very rarely the eulittoral sandstones are found to have the boring

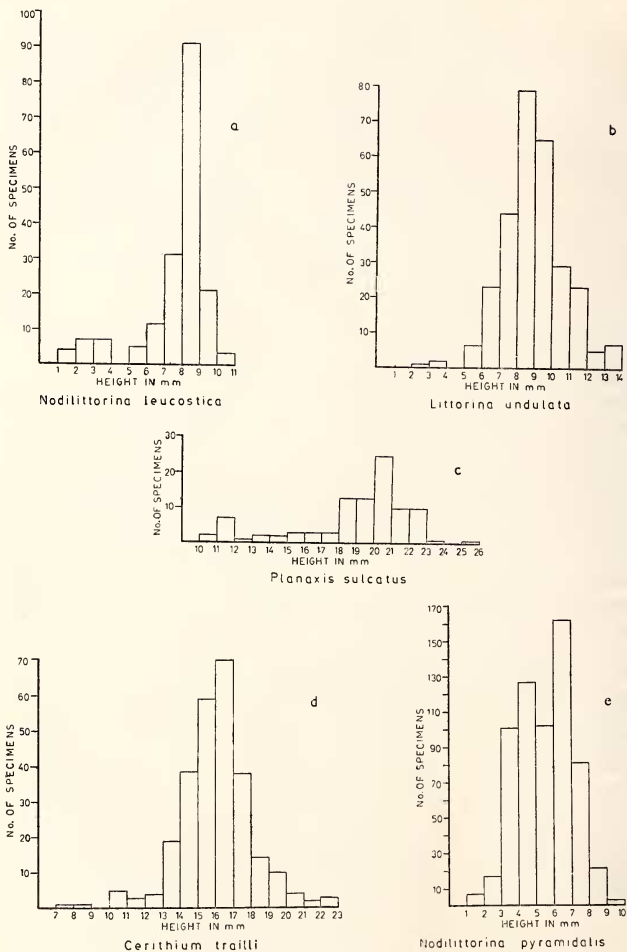


Fig. 2. Size range of some intertidal gastropods collected from sample plots at different stations. a. *Nodilittorina leucostica* from Station 4, during January, 1974. No. of specimens measured 180. b. *Littorina undulata* from Station 4, January, 1974, based on 284 specimens. c. *Planaxis sulcatus* from Station 5, September, 1973, based on 96 specimens. d. *Cerithium trailii* from Station 5, September, 1973, based on 271 specimens. e. *Nodilittorina pyramidalis* from Station 4, January, 1974, based on 621 specimens.

bivalve, *Lithophaga* (Appukuttan 1972).

Raised reefs

The raised reefs of Ramanathapuram in South India are already described (Foote 1889, Sewell 1935, Stoddart and Pillai 1972). Two stations, 5 and 8 were studied for their living molluscs, and were found to be mostly similar to the elevated sandstones discussed earlier. This includes both the littoral fringe and eulittoral forms.

Mangroves

Mangroves are characteristic of areas with variable salinities, muddy or sandy bottom and calm conditions (Cooman 1969, Macnae 1968, Macnae and Kalk 1962). The molluscan fauna of mangroves in general includes a limited number of gastropods and bivalves. There appears to be no earlier information on the mangrove fauna of this area, though Stoddart and Fosberg (1972) have recently listed the vegetation and discussed the zonation at Manauli Island (Station 14). The molluscan fauna associated with the mangroves can be broadly divided into those that actually live on the vegetation and those that live around. At station 14 the mangroves are of *Avicennia marina*, *Bruguiera cylindrica* and *Rhizophora mucronata*. *A. marina* forms a low wooded forest. According to Macnae and Kalk (1962) the animals found in the mangroves are only fortuitously associated depending on the level of water table, resistance to waterloss, demand for protection from sun, degree of consolidation of substratum and availability of food.

The breathing roots of *Avicennia* at Manauli Island are inhabited by *Planaxis sulcatus* often mixed with *Littorina melanostoma*. They are found 50 cm above the lowest water-mark. On the trunks and leaves of trees, *L. scabra* occupy upto one and a half metres

from the ground level. Other conspicuous animals on the roots are the barnacles. The spaces among the breathing roots in the eulittoral zone harbours *Cerithidea fluvialilis* in plenty. The gastropod *Cassidula* sp. was also collected. The only bivalve we could find in the ground was *Gafrarium tumidum*, a species that is found commonly in several other habitats.

It is interesting to compare the mangrove-associated molluscs of this area with those of the East Indies and Western Indian Ocean, though the information from this part is by no means complete. Both *L. melanostoma* and *Cassidula* sp. are listed as true mangrove forms of the East Indies (Cooman 1968). *Cerithidea* is common to East Indies and Indian Coast, but the species listed by Cooman from the East Indies is different. Cooman (1968) lists 20 species of molluscs from the East Indies against six species we have collected from here. *Isognomon*, *Crassostrea*, *Modiolus* and *Teredo* found in the mangroves of East Indies do occur in other habitats in south India, though we could not collect any of them specifically from the mangroves we investigated. *L. scabra* is common to southern and western Indian ocean mangroves (Taylor 1968) but is not known from East Indies. *L. melanostoma* found in southeast coast of India and eastern Indian mangroves is not listed from western Indian ocean. In this respect, our mangroves have faunal elements from both eastern and western Indian oceans. However, there is need for more intensive collection of the faunal elements of our mangroves.

Eulittoral Boulders

a. Semifossilised loose lying corals:

At Manacadu Point (Station 5) the raised reef gradually dips into the sea with a lot of

semifossilised loose lying coral boulders of *Favia*, *Favites*, *Platygyra*, *Porites*, *Goniastrea* and *Acropora* having a coating of green algae. The boulders are exposed at almost every tidal change and are covered only at the spring tides. These were found to be an ideal habitat for many algal grazing gastropods. *Planaxis sulcatus* are abundant and occupy the highest position in the vertical range of distribution. They show a tendency to crowd together in small crevices and depressions of the boulders and those of the same size are found together. In September, 1973 there were 120 to 130 individuals per square metre and their size ranged from 10 to 25 mm. Very small animals were not seen and this suggests that their reproductive period probably coincides with that of *Littorina* at the tail end of the southwest monsoon. The size range of 96 specimens, all from a sample plot is presented in Fig. 2C, and it shows that the maximum number of individuals was within the range of 20 to 21 mm. *Onchidium verruculatum* was very common on the undersides of the boulders inhabited by *Planaxis*. At fully exposed condition, four to five individuals were found crowded together in crevices. Lower in the vertical range there is a preponderance of *Cerithium trilli*. The zone of *Cerithium* is subjected to lesser duration of exposure than the zone of *Planaxis*. There is a clear-cut demarcation between the zones of *Planaxis* and *Cerithium* and we failed to observe any mingling of the two genera. It is likely that *Cerithium* is less tolerant to exposure than *Planaxis*. The number of individuals of *Cerithium trilli* per square metre averaged 286 with an average total weight of 204 gm. In size they ranged from 7 to 22 mm during September, 1973; specimens of smaller size were apparently absent. The maximum number of individuals was seen in the size

range of 10 to 17 mm (Fig. 2d). From the analysis of the size range of individuals during September, it is clear at these gastropods also breed during the tail end of southwest monsoon as in the case of littorinids. The smallest ones (7 to 8 mm) belonged to the latest brood.

Below the zone of *Cerithium*, *Nerita* was very common, represented by at least three species, viz. *N. maura*, *N. albicella* and *N. chaemelon*, found in a totally exposed condition. Mingled with *Nerita* were seen four species of *Gafrarium*, viz. *G. pectinatum*, *G. dispar*, *G. divaricatum* and *G. tumidum*; however, *Gafrarium* has a wider range of habitat selection and is often found on the sandy and vegetated lagoon bottom. *Crassostrea cucullata* is common here.

b. *Eulittoral granite boulders:*

At station 3 the groynes of the jetty form an excellent artificial habitat for many gastropods. At low tide, these blocks get exposed for a long time, and reveal underneath the loose boulders, several species such as *Purpura rudolphi*, *P. carnifera*, *Conus amadis*, *C. coronatus*, *Cypraea moneta*, *C. caputserpentis* and *Aplysia lineolata* occur. On the surface of boulders *Trochus radiatus* and *Turbo intercostalis* were seen. Bivalves were not seen, though *Mytilus*, recently introduced by the Institute, for mariculture experiments was thriving.

c. *The reef crest and reef flat:*

There seems to be no well demarcated reef crest or reef flat in this area since the fringing shallow reefs have not developed into a well consolidated structure. Further, whatever existed has been destroyed in many places. In an earlier paper Pillai (1971a) used the term reef crest to denote the highest part of the reef in Palk Bay. This part of the reef is



1. The raised reef and eulittoral coral boulders at Station 5, teamed with *Planaxis* and *Cerithium*.
2. Eulittoral sandy beach at Mandapam Palk Bay, where *Donax* is plenty. One of the Sample plots is seen in foreground.

composed of dead boulders subjected to intermittent exposure as in a typical reef flat. An area similar to reef flat with a boulder zone is present at Krusadai Island (Station 10) and is subjected to heavy breakers. In the Palk Bay, *Trochus radiatus*, *Turbo intercostalis*, *Astrea semicostata* and *Drupa margiritica* are seen at the top of the boulders subjected to prolonged exposure at low tides. On the sides of the boulders, at a lower level, *Arca* spp. and *Isognomon isognomon* are rarely seen. *Crassostrea cucullata* is common. *Pinctada* sp. is also rarely seen. At Krusadai (Station 10) the fauna was found to be rich and varied, probably due to the undisturbed condition of the reef. Gastropods were very common and were represented by *Cerithium morus*, *Pyrine versicolor*, *P. zebra*, *Drupa margiritica*, *D. tuberculata*, *D. horrida*, *Cypraea arabica*, *C. moneta*, *Trochus radiatus*, *Turbo intercostalis*, *Thais (Purpurea) rudolphi*, *Cantharidus undosus*, and *Nerita albicella*. Among the Amphineura a species of *Ischnochiton* was very common. Bivalves were poorly represented, but for the presence of young specimens of *Crassostrea cucullata*.

The submerged or sublittoral habitats

a. The unvegetated sand:

At several spots in Palk Bay and Gulf of Mannar, the bottom sand is clean and fine grained, (Pl. 2, Fig. 1) with an admixture of clay and dead shells at the subsurface, often with a foul smell. The muddy subsurface is unsuitable for burrowing bivalves and digging scarcely revealed the presence of any infauna. On the surface, *Drupa margiritica*, *Cerithium* spp., *Murex tarpa*, and *Bursa spinosa* are generally seen. However, the ideal habitats of all these animals are elsewhere, and many bivalves are seen either lying on the surface or partly buried, like *Gafrarium tumi-*

dum. At Manauli Island, *G. tumidum* is found along with *Macra cuneata*, *Dosinia cretacea* and *Mesodesma trigona*. The mud flats were found to be teeming with *Cerithidea fluviatilis* in Manauli Island. The other gastropods rarely seen are *Nassa thirstis* and *Polinices mamilla*, the former generally harbouring a symbiotic anemone on the shell. The younger specimens of *P. mamilla* are purple whitish while the adults are milky white and feed on bivalves (Taylor 1968). *Cardium edulae* occurs in Palk Bay and their dead shells are found on the surface. Rarely *Pinna bicolor* is seen half buried in sand, though it is abundant on seagrass beds.

b. Submerged dead coral shingle:

At Station 5a, the lagoon bottom is strewn with loose, semifossilised coral boulders with intermittent sandy areas. The nature and composition of the boulders are similar to those already described from Station 5. The sandy areas have many algae like *Sargassum*, *Padina*, *Turbinaria* and the calcareous alga *Amphiroa*. For details of the algae reference may be made to Rao (1972). The depth at lowest tide is about 50 cm. These boulders harbour a rich and varied fauna of molluscs, especially bivalves. Most of them are found attached to the boulders, the most common being *Arca* represented by at least three species, viz. *A. symmetrica*, *A. avellana* and *A. complanata*. The swimming bivalve *Galeomma paucistriata* occurs in fair numbers. It is pale yellowish white with a dark brown prolongation of the mantle in the living condition (Satyamurthi 1956). Yet another very common bivalve seen here is *Scintilla*, represented by two species, viz. *S. hanleyi* and *S. timorensis*. *Vulsella vulsella* with its commensal sponges is fairly common. *Isognomon isognomon* and *Pinctada anamoides* are found in fair numbers. The

larger specimens of *P. anomoides* ranged from 50 to 65 mm in length. Gastropods are by no means a conspicuous element in the fauna of this habitat, though *Drupa margiriticola*, *Cerithium trilli*, *Turbo intercostalis*, *Cellana radiata* and *Eumarginula obovata* are represented.

c. *The sea grass fauna:*

At station 2, 6a & 13 the sea grass vegetation is composed of *Cymodocea rotunda*, *C. serrulata*, *Halodule* sp. *Syringodium isoetifolium* and *Thalassodendron ciliatum* (Stoddart & Fosberg 1972). They are locally abundant at several places both in Gulf of Mannar and Palk Bay. Grass beds are excellent habitat for burrowing molluscs while their leaves and stems afford substratum and protection to epifaunal elements (Taylor & Lewis 1970). Among the epifauna of this area the bivalves are represented by *Gafrarium tumidum* and rarely *Circe scripta*. *Cyprea histrio*, *C. arabica*, *Murex virgineus* and *Cerithium scabridum* and *C. trilli* the last two being found on the leaves and stems of sea grass. Yet another common gastropod, *Pyrene* seen on the leaves and stems is represented by three species, *P. versicolor*, *P. vulpeula* and *P. flavida*. However, *Pyrene* is more abundant on various algae (*vide infra*). During January-February young ones of *Trochus radiatus* and *T. stellatus* were seen on the leaves, the adults of which are common inhabitants of eulittoral hard substratum. *Neritina oualaniensis* is also found in Manauli Island. The opisthobranch *Dolabella rumphii* was found in fair numbers at Station 2 during January, 1974.

The molluscan fauna of the grass beds in this area is dominated by *Pinna bicolor*, and a variety of animals found attached on their shells. There is a very heavy concentration of *Pinna* at Station 2 which is near a sewage

outlet. A similar situation in Seychelles, where sewage disposal encouraged the settlement of *Pinna* was recorded by Taylor (1968). The larger specimens in Gulf of Mannar measure 30 to 35 cm in shell length and as many as 15 are found per square metre at sites of high concentration. A few species of molluscs such as *Modiolus metcalfei* and *M. carvalhoi* among the bivalves and *Ischnochiton* among the Amphineura and *Neritina oualaniensis* among the gastropods are found attached on the shells of *Pinna*.

d. *Alga associated molluscs:* (Fig. 3)

Stations 3a, 7, 11a and 13.

The sublittoral algal communities afford a very suitable habitat for both young and adult molluscs. The common algae, searched for their molluscan macrofauna were *Sargassum*, *Turbinaria*, *Padina*, *Ulva*, *Caulerpa*, *Gracilaria*, *Gelidiella* and *Hypnea*. The molluscan assemblage associated with each of these is briefly presented below.

Ulva reticulata forms extensive green patches in the lagoon bottom of Palk Bay along Mandapam during July to October and is often found washed ashore in large quantities. (Pl. 2, Fig. 2). Many gastropods are found attached to this alga, such as *Catharidus interruptus*, *Thais tissoti*, *Cerithium scabridum*, *Drupa margiriticola*, and *Trochus radiatus* (very small ones 3 to 5 mm in diameter) and *Planispira fallaciosa*. Almost all the specimens collected were young ones, their adults being characteristic inhabitants of other substrata.

Caulerpa racemosa is common on the reefs and other isolated hard substrata. Many nudibranchs are reported to be associated with this alga, though our collection yielded none. The bivalve gastropod *Berthelinia limax* was found in fair numbers in Palk Bay. These animals have a brilliant green colour, perfectly

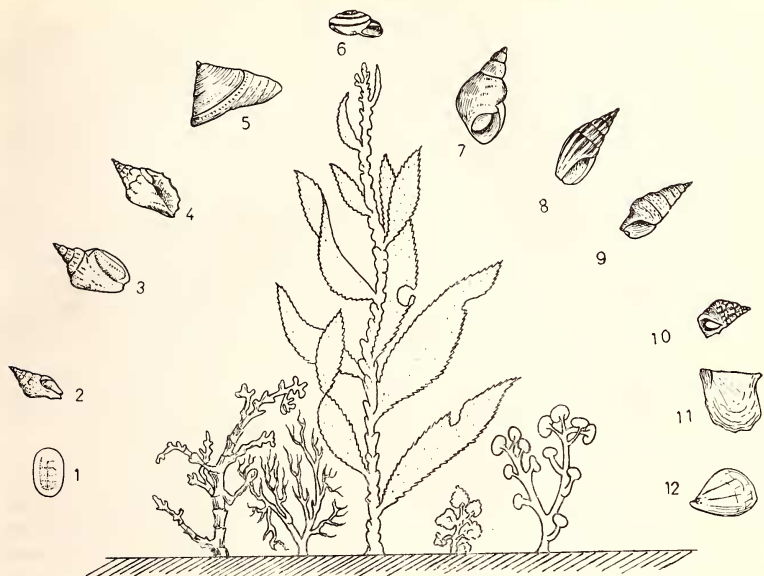


Fig. 3. A general representation of the molluscs associated with various algae.

1. *Ischnochiton* sp. $\times 2.5$; 2. *Pyrene zebra* $\times 1.3$; 3. *P. versicolor* $\times 1$; 4. *Drupa margiriticola* $\times 1$; 5. *Trochus stellatus* $\times 1$; 6. *Planispira fallaciosa* $\times 1.5$; 7. *Phasionella nivosa* $\times 1$; 8. *Pyrene vulpecula* $\times 1$; 9. *Cerithium scabridum* $\times 1$; 10. *Nodilittorina pyramidalis* $\times 1$; 11. *Pinctada anomoides* $\times 0.5$; 12. *Berthelinia linax*.

matching that of the alga, and it is difficult to spot the animals in the field. There seems to be a sort of specificity in the association between *Berthelinia* and *Caulerpa* and we failed to collect this mollusc from any other algae we examined. It may be noted that the first Caribbean bivalve gastropod, *B. caribbea*, was also recorded on *Caulerpa* (Edmunds 1962).

Padina gymnospora is found on the reefs and in the lagoon. There is a preponderance of this at Station 3a from where we collected several samples during January, 1974. At least four species of gastropods, viz. *Drupa tuber-*

culata, *D. margiriticola*, *Pyrene zebra* and *Trochus radiatus* were found on the leaves along with *Ischnochiton* sp. Bivalves were not represented. *Padina* is a less favoured habitat for molluscs when compared to other higher algae from the same locality such as *Sargassum* and *Turbinaria*.

Turbinaria sp. grows in patches in several places and was found to be common at station 3a. The economically important small gastropod *Pyrene zebra* is common on the stems and leaves of this alga. *Drupa margiriticola* and *D. tuberculata* also occur but in very few

numbers. *Planispira fallaciosa* and *Phasionella nivosa* occur rarely. Juveniles of *Trochus radiatus* were found in January with plantigrades of the bivalve *Modiolus* sp. *Turbinaria ornata* from Palk Bay yielded *Pyrene versicolor* a species which we could not collect from *T. conoides*.

Two species of *Sargassum*, viz. *S. wighti* and *S. myriosystem* are common here. On the former *Pyrene zebra* and *P. versicolor* are very abundant. Juveniles of *Trochus radiatus* and plantigrades of *Pinctada anamoides* are also rarely seen. *Sargassum* growing on hard substrata seems to be the most ideal habitat for *Pyrene* in this area.

Yet another common alga in almost all localities of both Gulf of Mannar and Palk Bay is *Gracilaria edulis*. *G. edulis* yielded *Pyrene versicolor*, *P. zebra*, *Phasionella nivosa* and *Drupa margiriticola*, *Cantharidus undosus* and *Astrea semicostata* though none of the species is common. During December-January, juveniles of *Trochus* were common. All the molluscs found on *Gracilaria* were gastropods.

Two species of *Hypnea*, viz. *H. musciformis* and *H. valentiae*, were found to be common on the sandstone blocks under the Pamban Bridge. (Station 7). In January, it was found that all the samples contained several plantigrades of *Modiolus* in the size range of 2 to 5 mm. Very rarely juveniles of pearl oysters were also seen. Juveniles of *Trochus*, *Cellana* and *Ischnochiton* were also collected. However, the commonest and most abundant molluscs associated with *Hypnea* during January was *Modiolus*.

A notable feature of the alga-associated molluscs of this area during the December-February period was the presence of a large number of juveniles of both gastropods and bivalves. These include those of *Trochus*, *Cellana*, *Cerithium*, *Cantharus* and *Pyrene* among

the gastropods, and of *Pinctada* and *Modiolus* among the bivalves. There exists a constant association between the developing stages of some bivalves such as *Mytilus edulis* and various filamentous algae (Colman 1940; Chipperfield 1953; Bayne 1964). It has been shown that mussels rarely settle on existing beds of adults, probably to avoid competition. The juveniles get attached and detached more than once on filamentous substrates before they finally get settled. The presence of juveniles of various molluscs on different algae indicates that there is no strict specificity during their primary settlement to any alga, all available filamentous substrata being utilised. The presence of juveniles during the December-January period is again an indication to the breeding period of these molluscs here coinciding with those of littorinids.

Coral-associated molluscs:

Corals afford a substrate for several types of animals, providing food and shelter. Mention has already been made of the molluscs associated with the reef flat and dead boulders. In the living corals, the branching forms provide loose interspace where many animals including molluscs can live free from the attack of predators. Massive corals provide attachment surface as well as penetrable substratum for boring animals (Morton and Challis 1969). The reef associated animals can be broadly divided into: *Hypobion*—those concealed in the shade or under the substratum; the *parabion*—composed of those animals living on the lighted reaches of living corals; and *epibion*—constituting those living on recently dead corals or algae. A fourth group is *cryptobion* composed of burrowing forms or those which live in the burrows of other animals (Morton and Challis 1969). Taylor (1971a) categorises reef-associated molluscs

into those that use corals as a convenient substrate for protection and the others that actually feed on coral polyps.

The structure of the living reef and the zonation of corals in this area have been already discussed by Pillai (1971a, 1971b) and Mergner & Scheer (1974). Though zonation on the fringing reef is indistinct, we recognise here an *Acropora* community to include ramose corals, a *Porites* community to designate massive corals dominated by *Porites* spp., and an *Echinopora* community to incorporate foliaceous corals such as *Echinopora* and *Montipora foliosa*.

The major components of the *Acropora* community are *Pocillopora damicornis*, *Montipora divaricata*, *Acropora formosa*, *A. corymbosa*, *A. hyacinthus*, *A. millepora*, *A. nobilis*, and *A. humilis*. *A. millepora* and *A. nobilis* are more common on the Gulf of Mannar reefs while *A. corymbosa* is abundant on the Palk Bay side. *P. damicornis* is omnipresent. Most of these small-polyped ramose corals establish themselves at the outer side of the reef where water is clearer and deeper (Pillai 1971a).

The branching corals seem to be favoured by many gastropods where they seek protection in the interspaces of branches and undersides. We could not collect any coral-eating molluscs. *Pyrene versicolor*, *Drupa* spp. and *Cerithium* spp. are common among the branches of *Acropora millepora* and *A. corymbosa*. *Trochus* spp. were found on the dead upper regions and bases of several colonies. *A. millepora* from Manauli Island yielded *Spondylus layardi*. *A. formosa* and *A. nobilis* with their arborescent coralla are less favoured habitats than the corymbose forms probably due to non-availability of closely placed branches that afford protection. On the dead parts of all ramose corals, *Crassostrea cucullata*, *Arca*

spp., *Isognomon isognomon*, *Pinctada* and *Lithophaga* spp. were seen.

Porites community (Fig. 4) forms the basic structure of the reefs in this area. *P. solida*, *P. lutea*, and *P. somaliensis* are fairly common both in the living and semifossilised condition. Among and on *Porites* are seen *Favia favius*, *Favites abdita*, *Favia pallida*, *Leptastrea* spp., *Cyphastrea* spp., *Platygyra lamellina* etc. (see Pillai, 1972 for the list of corals from this area).

Both gastropods and bivalves are found on the massive corals. A few gastropods such as *Drupa margariticola*, *Pyrene* spp. and *Cerithium* spp., were found crawling on the surface of massive corals. *D. margariticola* is abundant on the Palk Bay and a large number of them get into the traps set by the local fishermen for catching reef fishes. *Astrea senicostata* and *Planispira fallaciosa* are also seen. *Lambis lambis* is found between the massive coral heads, sometimes in the sandy areas; sometimes the living molluscs afforded substratum to small colonies of *Porites* or *Sideastrea*, the corals thus getting free transport. Among the bivalves attached to the surface and undersides of massive corals were *Arca* spp., *Isognomon*, *Pinctada* and *Crassostrea*. However, the intensity of surface living bivalves was more on the dead coral shingle than on the living corals.

The dead, and rarely living corals, harbour a rich and varied fauna of burrowing bivalves (Appukuttan 1972). The mytilids are by far the commonest. *Lithophaga* is represented by at least five species, viz. *L. nigra*, *L. gracilis*, *L. teres*, *L. stramineus* and *L. levigata*; *L. nigra* being the commonest. The lithophaga make deep burrows generally double the length of their shells. *Botulla cinnamomea* makes shallow burrows. The venerid bivalves *Venerupis macrophyllia* and the petricolid,

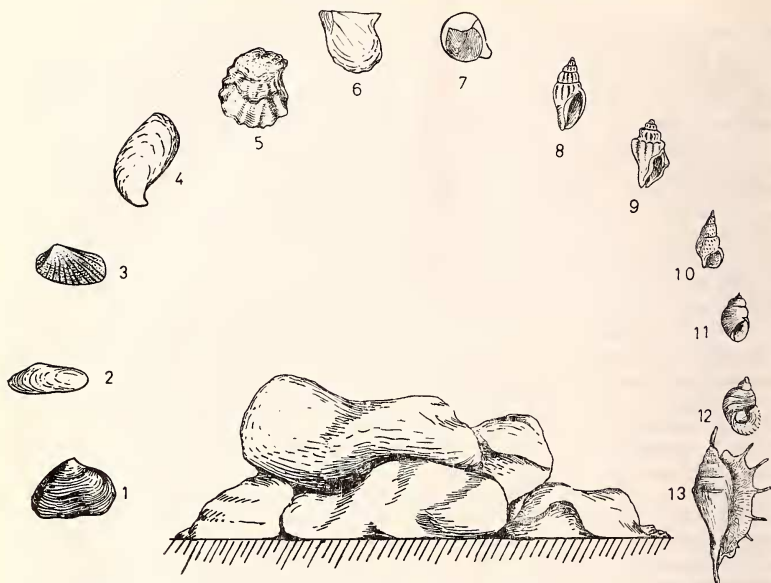


Fig. 4. A general representation of the molluscs associated with massive corals. 1. *Venerupis macrophyllia* $\times 0.5$; 2. *Lithophaga* spp.; 3. *Arca* spp. 4. *Isognomon isognomon* $\times 0.5$; 5. *Crassostrea cucullata* $\times 0.5$; 6. *Pinctada anomoides* $\times 1$; 7. *Jouannetia cumingii* $\times 0.5$; 8. *Pyrine* spp.; 9. *Drupa margariticola* $\times 0.5$; 10. *Cerithium trailli* $\times 0.5$; 11. *Nodilittorina leucostica* $\times 1$; 12. *Turbo intercostalis* $\times 1$; 13. *Lambis lambis* $\times 0.5$.

Petricola lithophaga and *P. divergence*, are also common in shallow burrows. *Aloides sulculosa*, *Gastrochaenia*, *Pholadides*, *Jouannetia*, *Parapholas* and *Clavagella* are the other common burrowing bivalves of this area [For others see Table 1, a detailed account of which has been already published by Appukuttan (1972)]. Though most of the burrowing forms are found in the dead parts of the corals, rarely *L. gracilis* was collected from the living parts of *Porites solida* and *Favia pallida*.

DISCUSSION

Species diversity and percentage composition

The percentage composition of the main molluscan groups in the collections from each habitat is presented in Table 2. The entire molluscan fauna found on the mangroves belongs to Gastropoda. Adult gastropods were more on the eulittoral boulders than bivalves, while the submerged shingle has the maximum (85%) concentration of surface living bivalves. The maximum number of species was

found in massive corals (38) of which 26 were bivalves, 18 of them being boring forras and the rest surface living. The mollusca of the littoral fringe was composed entirely of gastropods, while the eulittoral zone had 3.75% Amphineura, 68.5% gastropods and 27.75% bivalves. In the sublittoral molluscan fauna, Amphineura constitute 1.3%, gastropoda 38.7% and bivalves 60%.

Taylor (1971b) has attributed increased diversity of species in the sublittoral zone at Aldabra to tolerance of species to emersion. According to him (p. 206) this factor will account for the reduced diversity of species on higher shores. Those few species capable of inhabiting higher zones will exploit the available habitat resulting in a high density of population. In essence, the organisms of the intertidal zone are predominantly physically regulated communities and their major adaptations are of a physical nature, since the environment is subjected to varying physical factors. In the lower level (sublittoral) the animal communities are biologically controlled since the environment is mostly uniform. The biological inter-reaction result in a greater diversity of species (Sanders 1968). In such a situation the density of individuals of various species may not be as high as on the higher levels.

Factors Influencing the Distribution of Molluscs in Different Substrates

1) Adaptation to physical conditions:

Temperature tolerance and ability to withstand desiccation is the largest single factor that restricts the distribution of many intertidal animals. Smith and Newell (1955) have shown that the initial settlement of periwinkles takes place on a lower level, the upper tidal levels being later colonised by adults. A

similar phenomenon is shown here by *Nodilittorina pyramidalis* on sandstone. *Planaxis sulcatus* and *Cerithium trailli* occupy different levels, the former always being at a higher level at Mandapam. Ability to restrict the loss of water during exposure and the thickness of shell are major adaptations for a successful life on intertidal areas. Among the *Planaxis* and *Cerithium trailli* collected from the same station there was a notable variation in their fresh flesh and shell weight ratio. The ratios of flesh weight to shell weight in *Planaxis* and *C. trailli* were 1:7.2 and 1:5.8 respectively as calculated from 50 specimens from random samples. This clearly indicates a higher ratio in shell weight to that of flesh in *Planaxis* which will probably account for its ability to occupy a higher position in the vertical range of zonation, than *C. trailli*.

ii) Feeding relationship and distribution:

Availability of food is a major factor that influences the distribution of animals. The concentration of *Pinna bicolor* among the sea-grass beds is correlated with the availability of rich food from the plant material found in the sediments around (Taylor & Lewis 1970). The preponderance of *Pinna* near the site of sewage disposals lends further support to the view that supply of food for these filter feeders immensely influences their abundance. The presence of *Thias* (*Purpurea*) *rudolphi* and *Drupa margariticola* also appears to be correlated with their carnivorous feeding relationships. *Thias* feeds on *Cellana*, *Gafrarium* and other gastropod found on the upper zone of the eulittoral. *Polinices mamilla* and other gastropod found on the eulittoral zone feed on bivalves found on the same zone. The mangrove associated *Littorina scabra* are able to feed on mangrove vegetation. The occurrence of large populations of *Planaxis* and

TABLE I
LIST OF MOLLUSCS COLLECTED FROM DIFFERENT HABITATS WITH THEIR RELATIVE ABUNDANCE

No.	Name of species	1	2	3	4	5	6	7	8	9	10	11
		Raised reef	Sand-stone	Eulitoral boulders	Submerged Shingle	Unvegetated sand	Sea grass	Algae	Man-grove	Reef crest	Massive	Branching
Class Amphineura												
1.	<i>Craspidochiton</i> sp.	P										
2.	<i>Ischnochiton</i> sp.			C								
3.	<i>Emarginula obovata</i>			R								
Class Gastropoda												
4.	<i>Cellana radiata</i>		P	P								
5.	<i>Stomatella</i> sp.			R								
6.	<i>Cantharidus interruptus</i>							R				
7.	<i>Trochus radiatus</i>		P	P			R	P		P	P	
8.	<i>T. stellatus</i>			P				R		P	P	R
9.	<i>Turbo intercostalis</i>											R
10.	<i>Astrea semicostata</i>					R		R		R	R	
11.	<i>Phasionella nivosa</i>							P				
12.	<i>Nerita maura</i>			P						R		
13.	<i>N. albicilla</i>			R								
14.	<i>N. chameleon</i>											
15.	<i>N. plicata</i>		R									
16.	<i>Neritina oulaniensis</i>					R						
17.	<i>Littorina kraussi</i>		R									
18.	<i>L. melanostoma</i>								R			
19.	<i>L. scabra</i>								P			
20.	<i>L. undulata</i>	P	C	R							R	
21.	<i>Nodittorina leucostica</i>		C								R	
22.	<i>N. pyramidalis</i>	P	C									
23.	<i>Cerithidea fluviatilis</i>					C		R				
24.	<i>Planaxis sulcatus</i>	P		C					P			
25.	<i>Cerithium citrinum</i>											R
26.	<i>C. trailli</i>				P		R			P		
27.	<i>C. obeliscus</i>			C								
28.	<i>C. scabridum</i>			P	P		R	P				R
29.	<i>Lambis lambis</i>										R	R
30.	<i>Polynices mamilla</i>											
31.	<i>Cyprea arabica</i>			P						R		
32.	<i>C. caputserpentis</i>			P						P		

MOLLUSCS IN AND AROUND CORAL REEFS

33.	C. histrio	-	-	R	-	-	-	-	P	-
34.	C. moneta	-	-	P	-	-	-	-	-	-
35.	Bursa spinosa	-	-	-	R	-	-	-	-	R
36.	Murex virgineus	-	-	R	-	-	-	-	-	-
37.	M. trapa	-	-	-	R	-	-	-	R	-
38.	Drupa horrida	-	-	-	-	-	-	-	C	C
39.	D. margitricola	-	R	P	P	-	-	-	R	P
40.	D. tuberculata	-	-	-	-	-	-	-	-	-
41.	Thias (Purpurea) rudolphi	-	P	P	R	-	-	-	-	-
42.	Thias carnifera	-	R	-	-	-	-	-	-	-
43.	T. tissoti	-	-	-	-	-	-	-	-	-
44.	Pyrene flavida	-	-	-	-	R	-	-	-	-
45.	P. versicolor	-	-	-	-	P	C	-	P	C
46.	P. vulpecula	-	-	-	-	R	R	-	-	-
47.	P. zebra	-	-	-	-	-	C	-	C	-
48.	Cantharus undosus	-	-	-	-	-	R	-	P	-
49.	Nassa thesities	-	-	-	-	-	-	-	-	-
50.	Marginella angustata	-	-	R	-	-	-	-	-	-
51.	Conus amadis	-	-	R	-	-	-	-	-	-
52.	C. coronatus	-	-	R	-	-	-	-	-	-
53.	Haninoza sp.	-	-	R	-	-	-	-	-	-
54.	Aplysia lineolata	-	-	P	-	-	-	-	-	-
55.	Dolabella rumphii	-	-	-	R	-	P	-	-	-
56.	Berthelinia linax	-	-	-	-	-	-	P	-	-
57.	Cassidula sp.	-	-	-	-	-	-	-	R	-
58.	Onchidium verruculatum	-	P	C	-	-	-	-	-	-
59.	Planispira fallaciota	-	-	-	-	-	-	R	-	R
60.	P. vitata	-	-	-	-	-	-	-	-	-
	Class Bivalvia	-	-	-	-	-	-	-	-	-
61.	Arca avellana	-	-	-	P	-	-	-	-	-
62.	C. complanata	-	-	-	C	-	-	-	-	-
63.	A. fusca	-	-	-	-	-	-	-	P	C
64.	A. symmetrica	-	-	-	-	-	-	-	-	C
65.	Modiolus carvalliøe	-	-	-	-	-	-	-	-	-
66.	M. metcalfei	-	-	-	-	-	P	-	-	-
67.	Modiolus sp.	-	-	-	-	-	-	C	-	-
68.	Lithophaga gracilis	-	-	-	-	-	-	-	-	C
69.	L. levigata	-	-	-	-	-	-	-	-	P
70.	L. nigra	-	R	-	-	-	-	-	-	P
71.	L. stramineus	-	-	-	-	-	-	-	-	P
72.	L. teres	R	-	-	-	-	-	-	-	P

